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FROM LABORATORY TO FLIGHTDECK: PROMOTING OPERATIONAL ALERTNESS

Mark R. Rosekind, Ph.D.[1], LCDR David F. Neri, Ph.D. [1,2], and David F. Dinges, Ph.D. [3]

[1]NASA Ames Research Center, [2]United States Navy Medical Service Corps,
[3]University of Pennsylvania School of Medicine

Moffett Field, California, United States

Abstract

Human operators remain central to safe aviation operations. Fatigue, sleep loss, and circadian disruption created by flight operations can degrade performance, alertness and safety. An extensive scientific literature exists that provides important physiological information about the human operator that can be used to guide operations and policy. For example, there are human physiological requirements for sleep, predictable effects on performance and alertness with sleep loss, and patterns for recovery. The circadian clock is a powerful modulator of human performance and alertness and it can be disrupted in aviation through night flying, time zone changes, and day/night duty shifts. Scientific examination of these physiological considerations has established a direct relationship to errors, accidents, and safety. This scientific information can be incorporated into flight/duty/rest regulatory considerations. Managing fatigue in the complex and diverse aviation environment requires an integrated and multicomponent approach. These factors preclude a simple solution and managing fatigue will benefit from addressing education, hours of service, strategies, technology, design, and research. Concept development should be initiated to move beyond current flight/duty/rest regulatory schemes and toward operational models that provide flexibility and maintain the safety margin. One example of such a concept is proposed and an initial demonstration project is described. Aviation has established a strong safety record by identifying and proactively addressing potential and established risks. It is now time for aviation to meet the challenge of managing fatigue in flight operations.

Introduction

Maintaining safe aviation operations is a complex task. Components of the task range from large systems issues to the individual human operator. For the foreseeable future, the human operator (pilots, controllers, maintenance personnel, etc.), remains central to safe, efficient, and reliable aviation activities. Therefore, the importance of addressing human-related error, that accounts for approximately 70% of aviation accidents, remains critical to maintaining and improving safety (Ref 1). It is critical that the core human requirement for sleep be managed effectively and operations should reflect the fact that the basic properties of the circadian clock directly affect an operator's performance, productivity, and safety. Fatigue engendered by operational requirements can degrade human performance capability and reduce the safety margin. Extensive scientific research exists that clearly demonstrates the importance and role of sleep and circadian factors on human performance and operational safety. This scientific information can be applied to the operational issues posed by flight/duty/rest time policies that concern air carriers, regulators, operators, and the flying public. The application of relevant scientific data to flight/duty/rest time issues will be addressed in four areas. First, scientific findings related to sleep and the circadian clock will be presented to describe their role in core human function. Second, data will be described that demonstrate ignoring the importance of sleep and circadian factors can have significant safety consequences. Third, the task of merging the science with operational issues will be discussed. Fourth, the complexity and diversity of operational requirements demand a variety of approaches and potential directions will be suggested.

The Biological Imperative: Human Sleep Need and the Circadian Clock

Human Sleep Requirements

On average, most humans physiologically require about 8 hrs of sleep per night. When provided adequate time to sleep, humans can average about 8.25 to 8.5 hrs of physiological sleep (Refs 2,3). Laboratory studies use physiological measures (i.e., brain, eye, and muscle activity) of sleep quantity and quality and daytime sleepiness to determine the number of hours of sleep that provide an optimal level of waking alertness (Refs 4–6). It is important to distinguish this physiologically determined sleep requirement from both habitual and reported sleep amounts. Some studies have examined the reported amount of habitual sleep over time and other studies have collected one-time surveys inquiring about average sleep amounts. Overall, most adults report an average of about 7–7.5 hrs sleep per night (Ref 7). However, data obtained in controlled laboratory settings challenge whether this "reported" amount of sleep is sufficient for optimal levels of waking alertness. Studies have demonstrated that extending sleep beyond the reported 7–7.5 hrs of "usual" sleep significantly increases daytime alertness (Refs 3,8). Modern society has been implicated in the development of a chronically sleep deprived population. Based on survey results, investigators found that reported habitual sleep times for young adults in the early 20th century averaged about 9 hrs compared to the 7–7.5 hrs currently reported (Ref 9). The National Sleep Foundation recently commissioned a Gallop survey examining the report of daytime sleepiness in a random sample of 1,001 individuals. The findings demonstrated that 75% reported daytime sleepiness, with 32% of these reporting severe levels. Thirty-two percent reported that their sleepiness interfered with activities and 82% of the respondents believe that daytime sleepiness has a negative effect on their productivity (Ref 10).

These amounts are averages and there are individuals at both extremes of short and long sleep requirements. These sleep requirements change significantly with age (Ref 11). Younger individuals require more total sleep and this amount decreases to that needed by adults. Sleep structure also changes with age (e.g., less deep sleep, more awakenings in older adults and elderly). In summary, humans physiologically require about 8 hrs of sleep, though they report usual sleep amounts of about 7–7.5 hrs. When sleep is extended, there is a significant increase in daytime alertness.

Effects of Sleep Loss

Sleep loss is common and can be acute or cumulative. In an acute situation, sleep loss can occur either totally or as a partial loss. Total sleep loss involves a completely missed sleep opportunity and continuous wakefulness for about 24 hrs or longer. Partial sleep loss occurs when sleep is obtained within a 24-hr period but in an amount that is reduced from the physiologically required amount or habitual total. Sleep loss also can accumulate over time into what is often referred to as "sleep debt." Sleep loss, whether total or partial acute or cumulative, results in significantly degraded performance, alertness, and mood (Refs 7, 12–22).

The reduced human performance capability that results from total sleep loss is well documented (Refs 12–19). However, perhaps the most common occurrence in aviation operations is an acute partial sleep loss or the accumulation of a sleep debt. A review of the relevant scientific literature demonstrated that as little as two hours of sleep loss can result in "impairment of performance and levels of alertness" (Ref 7). Therefore, an average individual who obtains 6 hrs of sleep could demonstrate significantly degraded waking performance and alertness. Cumulative sleep loss also significantly reduces alertness and performance (Refs 20–22). Data have demonstrated that not only does the sleep loss accumulate but that the negative effects on waking performance and alertness also are cumulative and increase over time (Ref 21).

Sleep loss can significantly degrade human performance capability in diverse functions. For example, studies have demonstrated increased reaction time, reduced vigilance, cognitive slowing, memory problems, time-on-task decrements, and optimum response decrements (e.g., Refs 14,15,17,19). Performance variability also increases with sleep loss. Therefore, overall performance can be significantly reduced with an increased variability or unevenness in responding (Ref 17). Consider that these findings occur in some of the simplest performance challenges, such as reaction time to a single stimulus or minimal choice memory task. These basic psychomotor and cognitive functions are the foundation for any task requiring complex, higher-order performance.

An important phenomenon, highly relevant to operational environments, is that there is a discrepancy between the subjective report of sleepiness/alertness and physiological measures. In general, individuals will report higher levels of alertness than indicated by physiological measures (Refs 23–25). Data from an international study of flight crews had an example where the highest subjective rating of alertness occurred at a time when physiologically the individual was falling asleep within 6 minutes (an indicator of severe sleepiness) (Ref 23).

<u>Recovery from Sleep Loss</u>

There are two factors to consider when determining requirements for recovering from a sleep loss situation. First, when does the internal sleep architecture return to baseline levels. Second, when do waking performance and alertness levels return to their baseline. After sleep loss, recovery is not accomplished through an hour for hour restitution. Even after prolonged wakefulness of 264 hrs, the initial recovery sleep will last 12–15 hrs (Ref 26). Rather, recovery is accomplished through an increase in deep sleep (NREM slow wave sleep) observed starting on the first night of regular sleep (Refs 27–29). Generally, two nights of recovery sleep are needed to resume a normal baseline pattern (Refs 27,30), though this can be dependent on the duration of the continuous wakefulness. Also, typically, two nights of recovery sleep are needed to return to a normal baseline of waking performance and alertness (Refs 21,31), though this too can be dependent on the length of prior wakefulness (e.g., Ref 3).

<u>Long-Term Effects of Sleep Loss</u>

There are no definitive morbidity and mortality studies that provide an absolute answer to the long-term effects of sleep loss. However, there are some provocative published studies that indicate there are effects on health and longevity. For example, chronic sleep loss/disruption can be associated with physical complaints (Ref 32) and reported short and long sleep is associated with reduced longevity (Ref 33). The most severe effect has been a documented genetic anomaly that triggers significant sleep loss and eventually death (Ref 31). A series of animal studies have demonstrated clearly that prolonged sleep loss results in a syndrome that eventually leads to death (Refs 35–39).

<u>The Circadian Clock</u>

Besides sleep, the other major physiologic determinant of waking performance and alertness is the internal circadian clock (Refs 40–42). Circadian (*circa* = around, *dies* = day) rhythms fluctuate on a 24 hr cycle with peaks and troughs occurring in a regular pattern. These patterns are controlled by a circadian pacemaker located in the suprachiasmatic nucleus (SCN) of the hypothalamus. The SCN is the circadian timekeeper for a wide range of human functions, including physiological, performance, behavioral, mood, and sleepiness/alertness. One of the most prominent is the 24 hr sleep/wake cycle programmed for a daytime period of consolidated wakefulness and a nighttime period of consolidated sleep. There are circadian patterns for cognitive and psychomotor performance, physiological activity (e.g., digestion, immune function, thermoregulation, DNA synthesis), alertness, and mood (Refs 43–47). Even birth and death have circadian patterns that peak during the night (see Ref 40).

Body temperature is often used as a marker of the internal circadian clock (sometimes referred to as the “hands of the clock”). The trough or low point of the clock is around 3 am to 5 am with many functions demonstrating reduced levels from 12 am to 6 am. The lowest level of function (e.g., alertness, performance, subjective mood, temperature) occur within the 3 am to 5 am trough. Sleepiness has a bimodal distribution, showing the most severe low at 3 am to 5 am with a less marked but significant expression between roughly 3 pm to 5 pm. This afternoon increase in sleepiness occurs whether a meal has been consumed or not, though the meal may exacerbate the underlying sleepiness (Ref 48).

Zeitgebers (“time givers”) are cues that synchronize circadian rhythms to their 24-hr pattern. To date, light has been demonstrated to be among the most powerful zeitgebers to synchronize the circadian pacemaker. Bright light can dramatically shift the phase of the human circadian clock when applied at responsive times in the 24 hr cycle (Refs 49–51). Without cues, the intrinsic rhythm of the clock is longer than 24 hrs. Generally, data have demonstrated a free-running periodicity approximating 24.9 hrs, though recent findings suggest this may be closer to 24.2 hrs (Refs 40–42,52). An intrinsic period longer than 24 hrs provides an inherent tendency to support circadian delays (e.g., staying awake longer) and opposing advances (e.g., trying to go to sleep earlier).

Moving to a new light/dark schedule (e.g., nightwork or time zone change) can create internal and external desynchronization. These involve an internal desynchrony among circadian rhythms and/or a discrepancy between internal SCN timing and external/environmental cues. The internal clock can take from several days to weeks for adjustment or in some circumstances not fully resynchronize. Scientific studies have demonstrated these findings in the laboratory and aviation field studies conducted during actual flight operations (Refs 40–42, 53–63).

<u>Sleep and Circadian Factors Affect Errors, Accidents, and Safety</u>

An extensive scientific literature has emerged that clearly demonstrates the significant role that fatigue, sleep loss, and circadian factors play in creating errors and accidents. Several reviews have provided solid scientific evidence that relate these physiological factors to safety, health, and public policy concerns (Refs 64–70). These examinations range from large studies of accident databases to in-depth analyses of individual accidents. These occurrences are related to the degraded performance and alertness associated with sleep loss and circadian factors. As previously described, human performance capability is significantly reduced with acute and cumulative sleep loss. Circadian factors also degrade performance and are related to errors and accidents. Many studies have demonstrated the decreased performance and the increased errors and accidents associated with nightwork and the window of circadian low (about 3 am to 5 am) in operational settings (e.g., Refs 70–79). These findings range from reduced response speed on a variety of tasks to missing warning signals to minor hospital accidents.

Fatigue-related accidents have been identified in all modes of transportation and diverse shiftwork settings. The National Transportation Safety Board (NTSB) identified fatigue as a probable cause in 57% of fatal-to-the-driver truck accidents (Refs 80,81). Others have documented the extensive role of fatigue and sleepiness in car accidents (e.g., Refs 65,70,82–84). There have been high visibility marine accidents attributed to fatigue, including the *Exxon Valdez* grounding and the *World Prodigy* off the coast of Rhode Island (Refs 85,86). Between 1987 and 1992, the NTSB identified at least four major railroad accidents in which fatigue was identified as a primary cause (Ref 68). Fatigue has been identified as a probable cause of a major aviation accident and examined for its role in a series of aviation investigations by the NTSB (Refs 87,88). Diverse shiftwork settings have been the site of significant fatigue-related accidents. For example, the nuclear power plant accidents at Three Mile Island and Chernobyl occurred in the middle of the night (89–91). Healthcare is another around-the-clock setting where fatigue is a patient safety issue. In 1984, a young woman died in a case that later identified inadequate supervision of the medical resident and fatigue for interfering with appropriate treatment (Ref 92). Even the challenges and inherent risks associated with space travel and exploration can be exacerbated by fatigue. The Presidential Commission on the Space Shuttle *Challenger* Accident identified sleep loss as at least contributory to senior managers' poor decision-making regarding launch (Ref 93). Accident investigations and extensive databases are now available from all transportation modes and diverse work environments. The previous illustrations provide only a few of the available examples that have linked fatigue to errors, accidents, and reduced safety.

A current challenge in this area is to reliably determine the extent to which fatigue and sleepiness contribute to overall accident rates. Unfortunately, there are no accepted criteria or a structured approach to evaluate the role of fatigue in an accident investigation (and no "blood test for fatigue"). Though, there are examples where criteria and methods have been suggested and successfully applied (Ref 87). In many instances, no data on sleep and circadian factors are collected in any aspect of an accident investigation. For example, in over 30 states, the report form for car accident investigations does not have fatigue on the list of possible causal factors. Identified causal factors such as inattention or distraction, or a single car accident when a driver drifts off the road with no signs of braking prior to impact, should be considered cardinal signs for a potential fatigue or fall-asleep-at-the-wheel accident. Until well-established guidelines and specific evaluation criteria are established and subsequently applied to large prospective accident investigations, fatigue-related accidents will continue to be underestimated. In spite of these limitations, some estimates put the rate for accidental injuries and deaths related to sleepiness as high as 41%, while others posit a rate of 1–2% (Refs 94–96).

Another approach to providing relative estimates for risk or the role of fatigue will be to provide an accepted metric for comparison. For example, a recent study determined an equivalency between sleep loss and blood alcohol concentration (Ref 97). Using a standardized performance test in both sleep loss and alcohol consumption conditions, investigators could provide a blood alcohol concentration metric to compare results from the sleep loss condition. Results demonstrated that after 17 hours of continuous wakefulness, cognitive psychomotor performance decreased to a level equivalent to a blood alcohol concentration of 0.05%. After 24 hours of continuous wakefulness performance was approximately equal to a blood alcohol concentration of 0.10%. This approach provides a metric already accepted in other safety domains and allows some comparison for fatigue equivalency.

Extensive data are now available that clearly establish fatigue as a significant safety concern in all modes of transportation and in 24-hr shiftwork settings. However, there are other associated costs of fatigue, such as decreased performance and productivity, financial costs of accidents and reduced productivity, and potential liability issues. Estimates are available that provide costs associated with a single large vehicle accident ($57,000) and when fatalities are involved ($2.7 million) (Ref 98). These types of calculations will allow more useful cost/benefit estimates when considering strategies to address fatigue in transportation. The National Commission on Sleep Disorders Research estimated that in 1990, the direct cost of sleep disorders and sleep deprivation was $15.9 billion in the United States. Other estimates calculated for the National Commission determined that there were $46 billion a year in sleep-related accident costs and that diminished productivity due to shiftwork cost approximately $70 billion per year (Ref 64). Liability issues are emerging when employers are held responsible for work hours and subsequent consequences (e.g., an accident driving home from work) (Ref 99). Fatigue, sleep loss, and circadian disruption have emerged as significant and costly safety, productivity, and public policy issues.

The Challenge: Merging Science with Operations

Solid scientific data exist that can guide operational policies. For example, four core operational issues where scientific data are available to support policies will be addressed. Issue one: the critical foundation for optimal performance and alertness during operations is established by an appropriate quantity and quality of sleep prior to duty. Scientific data are clear regarding the human physiological requirement for 8 hrs of sleep to maintain performance and alertness. Are there individual differences and can individuals in certain circumstances operate on less than 8 hrs of sleep? The answer to both questions is yes. However, policies should address average requirements and not rely on the “extra” effort required to cope with sleep loss in nominal operations. As previously addressed, reported and habitual sleep amounts are not necessarily indicators of an individuals actual sleep need. Therefore, one core operational issue is establishing a minimum rest that provides for an 8 hr sleep opportunity every 24 hrs (Refs 2–22).

Issue two: length of continuous wakefulness. The complement to an appropriate minimum rest is the length of continuous wakefulness, traditionally identified as the duty time. Data from shiftwork studies comparing shift length (e.g., 8 vs. 10 vs. 12) have demonstrated a mixture of results up to a duration of 12 hrs. Some studies have demonstrated a difference at 12 hrs with significant decreases in performance and alertness and increases in errors and injuries (Refs 100–103). Data from NTSB aircraft accident investigations also indicate an increased risk beyond 12 hrs (Ref 88). Analysis of a national occupational-injury database showed a constant accident/injury rate through nine consecutive hours of work and then a progressive increase to three times the rate at 16 hrs of work (Ref 104).

Issue three: circadian factors/time of day. The circadian clock is a powerful modulator of human performance and alertness (Refs 40–48, 52–63). This is expressed in three forms in aviation operations: night flying, time zone changes, and day/night duty shifts. As previously discussed, the circadian trough (3 am to 5 am) and night in general (12 am to 6 am) is associated with significant degradation in performance and alertness and increases in errors and accidents. Therefore, the time of day that an operation occurs should be a consideration. The stability of performance during a 14 hr daytime duty period is not the same as during a 14 hr nighttime duty period. Time zone changes can significantly disrupt internal circadian physiology. Longer time spent in a new time zone may facilitate adaptation to the local environmental time, which may or not be advantageous to the operational requirement. In some instances, a quick turnaround and minimal adjustment to a new time zone may be more operationally relevant than a longer layover. Accommodations should be considered to facilitate adjustment in appropriate situations and provide longer recovery/readaptation time upon return to home time. Circadian disruption also occurs when switching between day and night flying in a short time period. The clock can not adjust to a fast day to night (or vice versa) schedule change.

Issue four: minimizing cumulative effects. It is important to maintain an optimal sleep opportunity every 24 hrs and also to address the potential for cumulative effects. Therefore, appropriate recovery time should be allowed per week (days or rolling hours). Scientific studies show that two nights of recovery sleep are typically needed to resume baseline levels of sleep structure and waking performance and alertness (Refs 3,21,26–31).

These are only four examples of common issues that confront aviation operations and scientific data are available to address other relevant issues as well. These particular four issues represent core processes which limit human performance and safety and often interact in aviation operations. For example, early report times, especially those that get progressively earlier across duty days, can create fatigue. In this situation, individuals undergo an acute partial sleep loss, that can accumulate across days, and may have to awaken and function during the circadian trough for performance and alertness. Reserve arrangements can be guided by the physiological requirements previously discussed. For example, reserve sleep opportunities should be predictable, protected, and of sufficient length.

Operational Complexity Precludes a Simple Solution

Aviation operations are diverse with many different requirements. There are uncertainties built into the system, including weather, mechanical considerations, and seasonal and regional variations. Given the complexity and diversity, it is unrealistic to expect that a simple solution or "one size fits all" policies will address all aspects of managing fatigue in flight operations. Besides these factors, other considerations come into play, such as economics, legal issues, and political agendas. However, in spite of these challenges, actions have been taken to move flight/duty/rest time issues into the modern age. The United Kingdom's CAP 371 incorporates scientific data and addresses complex issues such as circadian factors. This British regulatory scheme is in place and has been functioning successfully. The United States Federal Aviation Administration (FAA) has taken initial action to update the 1937 Federal Aviation Regulations (altered somewhat in 1985) with the publication of a Notice for Proposed Rulemaking (NPRM) on flight/duty/rest limitations. At the request of the FAA, one scientific input to their rulemaking was provided in the form of Principles and Guidelines that addressed duty and rest scheduling in commercial aviation (Ref 105). This unique document addressed general issues and principles supported by available scientific research with one approach to suggested guidelines. The Flight Safety Foundation, in a proactive safety project, established a working group that evolved these principles and guidelines for application to corporate aviation (Ref 106). Therefore, though complex and often contentious, these issues can be addressed to manage fatigue in aviation operations.

The Future: Moving Beyond Duty Time Limitations

Duty Time Considerations: Necessary But Not Sufficient

Governmental bodies have an established responsibility to the public to establish and enforce standards of safety. This responsibility is expressed in areas such as regulatory statutes that govern food and water standards, medical and pharmaceutical arenas, law enforcement, and policies to maintain a safe transportation system. The flying public expects governmental standards that will ensure safe aviation operations, ranging from equipment certification to procedures to flight/duty/rest considerations. Therefore, it is encumbent upon regulators and operators to bring flight/duty/rest policies into the 21st century and incorporate the available scientific data. Managing fatigue is a global issue and should be addressed from this perspective, providing a consistent approach.

While flight/duty/rest policies are one necessary component of addressing fatigue in aviation operations, they are not sufficient. As previously discussed, the operational environment is complex and diverse and therefore precludes a single and simple solution to managing fatigue. An integrated, multicomponent approach to managing fatigue in aviation operations offers more comprehensive improvements and potential flexibility. Besides hours of service considerations, there are at least five other areas that would comprise an integrated approach: education, strategies, technology, design, and research (Ref 107).

Education establishes the foundation for all other activities that address fatigue. Successful education and training modules exist for "alertness management in flight operations" and are in use in diverse settings around the world (Refs 108–110). There are a range of available strategies that can be implemented now to manage fatigue (Ref 111). One example is the scientific data demonstrating that a brief 40 minute inflight rest opportunity can significantly improve subsequent performance and alertness (Ref 112). There are a variety of technology approaches currently under investigation to determine their utility in identifying fatigue and performance decrements during operations (Refs 113–116). Some of these potential devices have application across modes of transportation and in shiftwork settings. A different technology approach is the development of predictive models and algorithms that could be used for scheduling design (Refs 117–123). Design considerations range from the construction of onboard crew rest facilities for augmented long-haul operations to the use of flight management computers to provide feedback to operators about their fatigue/sleepiness status. While significant scientific progress has been accomplished, there are many specific operational issues that would benefit from focused research (e.g., Refs 124–126). In some respects, managing fatigue in aviation operations is an optimization problem. Therefore, a combination of some or all of these components can offer an optimal result in addressing this complex issue.

<u>Future Evolution</u>

It is time to move forward with integrated and comprehensive programs that utilize available scientific research and a multicomponent approach to manage alertness and enhance performance capability on the job. Simultaneously, concept design, discussion, and action also need to be taken in moving to the future. The issue of managing fatigue in aviation operations eventually must move beyond current regulatory schemes. A full range of approaches and options should be considered. For example, a flight/duty/rest regulatory scheme, incorporating relevant scientific data, would be available as a standard for anyone to follow. As an alternative to following the regulatory scheme entirely or some aspects of it, operators could enact an accepted alertness management program. One possibility is the development of a structured program that provides operational flexibility beyond current regulatory schemes. This would be accomplished by providing an education program, personal and company strategies, and a method for collecting empirical data to determine performance and alertness on schedules outside the standard regulatory scheme. By establishing standardized methods, operators could collect information to determine whether a proposed schedule fits an accepted level of performance and alertness. Air carriers could develop their own databases to make comparisons across schedules and make decisions about augmentation, layover time, flight lengths, etc. based on empirical data. Clearly, it will be critical to establish the appropriate measures and to determine the criteria for accepted performance and alertness (i.e., safety). An air carrier might: 1) choose to completely follow the regulatory scheme, or 2) fly some schedules to the regulatory scheme and use the alertness management program to provide flexibility in some operational areas, or 3) undertake a program fully established through accepted empirical measures and performance criteria. This is only one example of a future evolution that could provide tremendous operational flexibility within accepted criteria for safety.

To examine the practicality, operational utility, and regulatory implications of such a concept, an initial program has been underway in New Zealand for the past 3 years. The NASA Ames Fatigue Countermeasures Program established a cooperative agreement with the New Zealand Civil Aviation Authority (NZCAA) to launch a pilot program with the components suggested above. The

NASA/NZCAA project was undertaken with the collaboration of Air New Zealand (ANZ) as an operational partner[1]. There were three phases to the collaborative project. The initial phase involved a collaborative NASA/CAA/ANZ field study in which the NASA team provided leadership and training on performance measures and analysis. This study was successfully completed and provided the foundation for the second phase (Ref 127). The second project involved reducing the number and intensity of measures obtained during a field data collection led by ANZ with NASA support. This project also was successfully completed and provided valid and informative data. The third phase of the project continues, as ANZ uses a sleep/wake log, actigraphy (behavioral estimate of sleep/wakefulness), and a vigilance performance measure (psychomotor vigilance task) to collect data. The data are collected on schedules with apriori determined operational issues, including augmentation, flight lengths, and layover lengths. NASA continues in an advisory role to evaluate data collection procedures and analyses, interpretation of results, and design issues. Preliminary results are encouraging with valid and informative data collected on a number of trip schedules (Ref 128). These data have been successfully used by ANZ to make operational decisions. The data are not the only factor considered but provide an empirical input previously unavailable to address the operational issues.

Aviation Must Meet the Challenge

Global demand for aviation operations continues to grow while generally, resources remain the same or may be reduced. Therefore, the safety and productivity issue of managing fatigue will remain, and potentially worsen, with increased growth and demand. Attempts to deny, minimize or distract from fatigue as an operational issue will only delay effective action while risk continues or increases. Other transportation modes have fully acknowledged fatigue as a safety issue that deserves attention and creative management solutions. For example, the 1995 Trucking and Bus Summit in the United States identified fatigue as its number one safety issue (Ref 129). This has led to a variety of activities (e.g., education, research, technology development) to address fatigue.

To meet this safety challenge, aviation should act on a variety of initiatives. A widespread educational requirement should be established to provide fatigue countermeasures training to all personnel involved in operations. There are extensive training requirements on many aspects of flight operations; fatigue is an issue that equals other safety considerations. Flight/duty/rest guidelines should be established that rationally incorporate the relevant available scientific information. There should be support for the development of new technology and scheduling models/algorithms. It will be critical to develop criteria for these technologies and models, implementation procedures, policies for use, and appropriate validation research (Ref 130). There should be full implementation of strategies already demonstrated to improve performance and alertness, such as planned cockpit rest (Ref 112). Also, now is the time to establish a mechanism for the development of future alertness management programs that will provide operational flexibility beyond standardized regulatory schemes.

Aviation has the respect and admiration of the flying public and other transportation modes for its extraordinary record of safety. It has reached this level of success by identifying and proactively addressing safety issues at all levels and across all components of the aviation system. However, with this success comes a tremendous responsibility to maintain this level of safety and when possible, improve it further. The time is now to fully and directly address the challenge of managing fatigue in aviation.

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